



<b>Document Title</b>	ISIS Cryogenic Supply Systems – Methane Specific Requirements		
<b>Used On</b>	TS1 Cryogenic Systems		
<b>Document No:</b>	ISIS-TS1-UPG-SRV-Sp-0011	<b>Issue No:</b>	1
<b>Author:</b>	R A Dean	<b>Issue Date:</b>	05/09/17
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## 1 Introduction

### 1.1 Purpose

This Technical Specification defines the specific requirements for the design and manufacture of the Methane Cryogenic Supply System (MCSS).

The requirements of this Technical Specification are in addition to those described in the companion document ISIS-TS1-UPG-SRV-Sp-0010 ISIS Cryogenic Supply Systems – General Requirements.

Requirements for the Hydrogen Cryogenic Supply System (HCSS) are given in the companion document ISIS-TS1-UPG-SRV-Sp-0012.

### 1.2 System Overview

The system is required to provide cryogenic liquid methane at stable temperature, pressure and flow rate at its outlet to the moderator vessel. The system is connected to the moderator vessel by a vacuum insulated transfer line (with concentric flow and return) routed through several meters of radiation shielding material.

All equipment is contained within a vacuum vessel in order to minimise heat loss, and refrigeration power is supplied from a Stirling Cryogenerator (see <https://www.stirlingcryogenics.com/> for more information).

The existing equipment has been operating successfully for over 30 years and it is therefore critical that no change is made which is detrimental to current operation. As a minimum, the new MCSS must retain all functionality of the existing system including:

- Provision of stable methane flow to the moderator within operating parameters.
- The capacity to replace the methane charge without the need for a shutdown.
- Connection with existing interfaces (methane pipework, vent system, vacuum system)
- Compatibility with existing control system and software.
- Compatibility with available space on the Target Services Trolley.

Additionally, improvements we are looking to implement in the new system include:

- A more effective means of continuously removing hydrogen gas and hydrocarbon polymer contaminants (see Section 1.3) from the methane during system operation.

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- Improved facility to flush contaminants out of the system during shutdown maintenance by the inclusion of drain points and purge points.

### 1.3 Radiolysis of Methane

Within the moderator vessel, the intense neutron radiation can cause the methane molecules to break apart into atomic hydrogen and free radicals of methane. These then recombine, forming molecular hydrogen (H<sub>2</sub>) and a variety of hydrocarbons. As the material is recirculated through the moderator over time, the hydrocarbon chains progressively increase in length, forming oils and waxes and eventually resulting in solid carbon-like deposits.

Hydrogen, which is gaseous at operating conditions, builds up rapidly within the existing system. After only a matter of hours of operation, the methane system experiences occasional pressure and temperature excursions, and the methane charge is partially replaced on a daily basis in order to mitigate this problem.

Oils are likely to be solid at operating conditions, and build-up of this material happens much more slowly. Approximately 100 – 200 ml of oil is drained from the existing system during a shutdown period at the end of each operating cycle.

A solution is therefore sought to allow continuous removal of contaminants from the fluid as it circulates, as this could allow the methane moderator system to run for a greatly extended period with much improved pressure and temperature stability.

## 2 Design Conditions

### 2.1 Overall System Design Requirements

The General Requirements for the supply of all equipment are given in the companion document ISIS-TS1-UPG-SRV-Sp-0010.

Design Pressure	:	Full Vacuum (0 barA) – 6 barG
Design Temperature	:	77 – 310 K
Process Fluid	:	Methane*
Operating Pressure	:	2-3 barA
Operating Temperature	:	110 K ± 1K
		NOTE: System should be capable of stable operation at 100K
Minimum Flow Rate	:	96.6 g/s
Refrigeration Power available	:	1000 W
Pressure Drop across Moderator and Transfer Lines at Operating Conditions	:	0.6 bar

\*Potential future development work may include using ethane or propane as process fluid. In this event the system may operate at different pressure and temperature. These shall not exceed stated design limits.

Additional loads resulting from equipment testing, for example the additional weight of liquid nitrogen, shall be considered.

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## 2.2 Heat Loads

Estimated values in current equipment at steady state operation

Moderator	:	0 - 300 W
Condenser	:	0 - 400 W
Heat Inleak	:	30 W
Transfer Line	:	60 W
Circulator Heat Input	:	60 W
<b>TOTAL</b>	:	<b>150-850 W</b>

## 2.3 Insulation Requirements

Total heat in-leak for all equipment within scope of supply shall not exceed 30 Watts.

Insulation shall be sufficient to ensure that temperature and temperature stability requirements are met for all functionality described in Section 3.

External surfaces shall be ice and condensation free at all times during operation.

Heat loads shall be minimised wherever possible / practicable and supplier shall provide evidence of how this is achieved.

Supplier shall provide specification of suitable insulation. It is anticipated that MLI shall be used on all appropriate surfaces.

# 3 System Functional Requirements

## 3.1 Modes of Operation

System operation is split into five main processes:

- System Cool Down
- Normal Operation
- Condenser Filling
- Methane Liquid Transfer
- Automatic Flow Recovery

Additionally, shutdown and routine maintenance operations will need to be considered.

### 3.1.1 System Cool Down

During initial start up the equipment shall follow the below procedure in order to achieve operating temperature.

- All system pipework (including transfer lines) is filled with gaseous methane to operating pressure.
- Circulation pump starts up to start circulating gas around system
- Cryogenerator is switched on to begin cooling the methane.
- Moderator bypass valve PV29M is opened, creating a 'short loop' within the coldbox system while still circulating a portion of fluid to the moderator.
- Methane cools as it circulates around the system. When pressure drops below the lower set point, Methane supply valve PV35M opens to add more gas to the system (flow is restricted



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to reduce pressure fluctuations). When pressure reaches operating pressure, PV35M is closed.

- If Cryogenerator temperature reduces to 93K, Cryogenerator is automatically switched off to prevent freezing of the methane (Cryogenerator restarts when temperature rises to 100 K).
- When temperature of return fluid from the moderator equalises with the 'short loop' fluid temperature, the moderator bypass valve PV29M is closed, sending all fluid through the moderator.
- Process continues until operational temperature is achieved.

Note that during this process, a significant period is encountered where 2-phase flow is present within the system.

In current operations, the duration of the System Cool Down process, from ambient temperature to operating temperature, is approximately 8 hours.

STFC recognises that cool down rate is largely dependent on the refrigeration capacity provided by the Cryogenerator. However, Supplier shall ensure that the equipment selection and system design allows a fluid flow to be maintained during the entire process, in order to provide constant and even cooling.

### 3.1.2 Normal Operation

System shall supply cryogenic liquid methane at stable pressure, temperature and flow rate controlled within the design values and tolerances given in Section 2.

Cold liquid methane flows in a continuous closed loop between the Cryogenerator and the moderator, driven by one circulator (while the other is on standby). The condenser vessel is closed to the main flow circuit and the moderator bypass valve is closed.

- Pressure is controlled in the main circuit within limits (upper / lower set point). If pressure drops below lower set point, Methane supply valve PV35M is opened and additional gas is added to the system until operating pressure is restored (flow is restricted to reduce pressure fluctuations). If pressure reaches upper set point, methane vent valve PV32M is opened until operating pressure is restored (additional bleed valve PV33M opens first at 0.2 bar below upper set point to reduce pressure fluctuations). Temperature is measured by Temperature Sensor TS71M at the coldbox outlet to the moderator. This feeds back into the PLC which then controls the power to the heater HTR77M.  
N.B. All control is carried out through the heater HTR77M - the Cryogenerator is operated at constant refrigeration power.

### 3.1.3 Condenser Filling

Requirements as per Normal Operation except that a portion of the process flow (nominally 15% but with the capability to be adjusted to any proportion) is diverted through the condenser vessel by Diverter Valve MDV13M. The condenser vessel remains closed to the main loop

It is critical that system temperature, pressure and flow rate stability requirements are maintained during Condenser Filling process.

Condenser filling is controlled by pressure using separate fill, vent and hysteresis valves. Condenser supply valve PV500M opens to fill condenser vessel until fill pressure set point (plus hysteresis) is



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reached. As the methane cools and condenses, the vessel pressure drops; when it drops below fill pressure, PV500M opens to add gas to the vessel. When fill pressure set point (plus hysteresis) is reached, PV500M closes.

A liquid level sensor LT 505M shall be incorporated in order to display the liquid level within the vessel

#### 3.1.4 Methane Liquid Transfer

The system shall have the capacity to partially replace the methane charge on a daily basis, following the procedure below.

- In advance of change out, liquid methane gradually accumulates in the condenser over a number of hours (typically 6 hours in current system) - see Section 3.1.3.
- The Methane Liquid Transfer process is initiated automatically by the MCSS control system.
- Condenser vessel supply valve PV500M opens to raise the pressure in the condenser vessel above system pressure.
- Cryogenerator and heater HTR77M stop. Circulator continues to operate.
- Diverter valve DV15M switches position to open between condenser and circulator (closed to Cryogenerator)
- Dump tank inlet valve PV308M opens.
- Valves downstream of the dump tank (PV14M and PV309M) close, so that all material is routed into the dump tank.
- Once the level in the condenser (LT505M) drops to Low Level Set Point the valve positions revert to normal operation positions.
- Approximately 1 hour after liquid transfer, the PLC initiates boil-off of Dump Tank contents using Dump Tank Heater HTR507M.

NOTE: Some disruption to Operating Conditions (temperature, pressure, flow rate) is expected as a result of the methane liquid transfer operation

The system must return to stable flow conditions within the design values and tolerances given in Section 2 within 30 minutes of methane liquid transfer operation

#### 3.1.5 Automatic Flow Recovery (AFR)

After methane change out is complete, additional action is often required in order to achieve stable flow, in the form of further liquid injection from the Condenser Vessel.

The MCSS control system constantly monitors the differential pressure across the circulators. If the  $\Delta P$  is drops below a threshold value, the AFR process shall be initiated.

The MCSS shall have the capability to carry out the following process:

- Condenser vessel supply valve PV500M opens to raise condenser pressure until it is greater than circulator inlet pressure.
- Diverter valve DV15M flicks over to open the condenser to the circulator for a fraction of a second ( $\approx 0.1$  secs) in order to inject liquid into the system. Valves then return to Normal Operations orientation.

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Valve opening is often required several times after a Methane Liquid Transfer before flow becomes stable. The PLC monitors the system continuously and will inject more liquid as described above if the  $\Delta P$  falls.

NOTE: Some disruption to Operating Conditions (temperature, pressure, flow rate) is expected as a result of the AFR operation

The system must return to stable flow conditions within the design values and tolerances given in Section 2 within 30 minutes of AFR operation

### 3.1.6 Shutdown for Routine Maintenance

During shutdown, the Cryogenerator is turned off and the methane allowed to warm up gradually to ambient temperature – no additional process heating is required. During this period, normal pressure control is maintained.

Once ambient temperature has been achieved, the system is subject to a purge/vacuum cycle (repeated 3 times) with helium in order to remove all flammable fluid.

After maintenance has been carried out, the system is subject to a purge/vac cycle (repeated 3 times) with helium in order to remove any air. The system is then subject to a purge/vac cycle (repeated 3 times) with methane in order to remove all inert gas. The MCSS is then ready for the system cool down process (see Section 3.1.1)

## 4 Mechanical Design of MCSS Components

### 4.1 Coldbox Vacuum Vessel

All equipment, except where stated, shall be enclosed within a single vacuum vessel.

The vacuum vessel shall be fitted with suitable provision to allow lifting into position.

Vessel material shall be austenitic stainless steel, Grades 304, 304LN or 316.

Pressure rating\*: Full vacuum (0 barA) – 0.5 barG

\*In combination with the Coldbox Vacuum Vessel Top Plate.

#### 4.1.1 Coldbox Vacuum Vessel Connections:

- Vessel top plate
- Port on underside of vessel for drain valve
- Port on underside of vessel for vacuum connection
- Port on underside of vessel for vacuum gauges connection

### 4.2 Coldbox Vacuum Vessel Top Plate

The Coldbox Vessel Top Plate shall be designed, in combination with the Coldbox Vacuum Vessel, to support all equipment contained within and all associated equipment above (for example circulator motors, valve actuators, etc.), including any additional loads resulting from equipment testing, for example the additional weight of liquid nitrogen

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The Coldbox Vacuum Vessel Top Plate shall be fitted with suitable provision to allow lifting into position. This provision shall have sufficient capacity to allow the Top Plate, Vacuum Vessel and all connected equipment and pipework (as supplied) to be lifted as one item.

#### 4.2.1 Coldbox Vacuum Vessel Top Plate Connections

With the exception of those connections listed in Section 4.1.1, all process, equipment and instrumentation connections shall be routed through the Coldbox Vessel Top plate.

Required connections include (but not limited to):

- Transfer line to moderator vessel
- 2 x circulators
- Valves
- Separator / separator flow and return
- Filter
- Temperature sensors
- Pressure sensors
- Liquid level sensors
- Vacuum overpressure relief device connection
- Flow meter
- Cryogenerator transfer line
- Process methane heater
- Dump tank heater
- Dump tank vent pipe
- Condenser supply/vent pipe

### 4.3 Cryogenerator Head Heat-Exchanger

Vacuum insulated unit containing:

- Heat exchanger with Cryogenerator head
- Connection to Gaseous methane supply / vent
- Dwell tank to allow H<sub>2</sub> Gas separation
- 2 x Temperature Sensors

Unit arrangement generally as per Drawing Pack Ref: *SI-7047-400* (note Item 9 - Heater coil is not required). Tenderers are encouraged to propose improvements to the design; in particular a reduction in overall dimensions is desirable.

Unit must be designed for attachment to existing Cryogenerator unit.

Vacuum insulation shall be linked to Coldbox Vacuum Vessel via Transfer Line (see Section 4.4)

### 4.4 Transfer Line to Cryogenerator

Vacuum insulated pipe to transport methane between Coldbox Vacuum Vessel and Cryogenerator Head Heat Exchanger.

Transfer line vacuum shall also provide a link between the insulation vacuums of the Coldbox Vacuum Vessel and the Cryogenerator Head Heat Exchanger.

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## 4.5 Internal Pipework

Supplier to design pipework in order to meet system operational requirements.

Pipework shall be fully welded except where identified, or where an alternative jointing method is unavoidable

Any non-welded joints used must be agreed by STFC.

Pipework layout should be designed to limit low points where oil/contaminants can accumulate.

Pipework layout should be designed to limit high points where gas bubbles can accumulate.

The Dump Tank should be the low point of the system and, where possible, pipework should drain to Dump Tank.

## 4.6 Condenser

### 4.6.1 Functionality

The Condenser is used to produce a new charge of liquid methane. It shall consist of a vessel incorporating a suitable heat exchange pipe. Process methane shall provide the refrigeration power.

Gaseous methane enters the condenser vessel. Process methane flowing through the heat exchange pipe will cool the methane to liquefaction point. Once the liquefaction has been achieved, the process methane will continue to sub-cool the new methane charge to operational temperature.

### 4.6.2 Design Requirements

Total capacity shall be 120% full system volume of liquid methane (including transfer lines and moderator vessel). The Condenser shall have sufficient overcapacity to retain an amount of liquid after Methane Liquid Transfer in case further liquid injection is required for the purpose of flow recovery.

The condenser shall provide sufficient cooling capacity (taken from the process flow) to produce a full liquid charge, however it is critical that this does not impose an unmanageable heat load on the system. The current system builds up a full charge (20 Litres) over approximately 6 hours, and it is expected a similar rate of cooling shall be achieved by the replacement system.

The Condenser must be adequately supported for full condition, and account taken for thermal contraction and expansion.

Suggested Layout is an annular vessel, with pipe carrying the process methane routed around the inner radius – see Drawing Ref: *SI-7046-150*.

### 4.6.3 Connections:

- Condenser Vessel supply/vent pipe
- Condenser Vessel outlet to main circuit
- Process Methane Inlet to Heat Exchange Pipe
- Process Methane Outlet from Heat Exchanger Pipe

### 4.6.4 Instrumentation:

- Liquid Level Sensor

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- Temperature Sensor
- Pressure Tapping into top of vessel

## 4.7 Dump Tank and Drain Valve

### 4.7.1 Functionality

The dump tank receives liquid from the main flow circuit during the Methane Liquid Transfer operation. Once closed off to the main flow circuit after Methane Liquid Transfer is completed, the methane is vented in a controlled manner from the dump tank using a heater to vaporise the liquid

As the methane is vaporised, it is anticipated that contaminant hydrocarbons (created by the neutron radiation) will remain in the tank. At ambient temperature these hydrocarbons present as a low viscosity oil. The tank must therefore be designed to collect this material and have the facility to be drained through a valve in its base during planned shutdown periods.

The unit should be designed such that, as material collects, the performance of the heater should not be degraded.

### 4.7.2 Design Requirements

Total capacity: Condenser Capacity + 50%

Pressure rating: Full Vacuum / 5 BarG Max

Dump tank shall have the facility to be vented in a controlled manner, without imposing a significant heat load on the rest of the system.

Dump Tank must be thermally linked to the condenser to ensure that the dump tank is cold when receiving liquid.

The Dump Tank must be adequately supported for full condition, and account taken for thermal contraction and expansion.

Dump tank shall have its own dedicated vent outlet.

Dump tank must incorporate a heater in order to vaporise the methane in a controlled manner.

Dump tank must have the facility to be drained of any accumulated oil. This operation must be able to be carried out without breaking into the main coldbox vacuum.

Drain valve shall be manually operated.

### 4.7.3 Connections:

- Supply pipe from main flow circuit
- Vent pipe
- Drain outlet
- Methane Heater (currently approx. 100 W)

### 4.7.4 Instrumentation:

- Liquid Level Sensor
- Temperature Sensor
- Pressure Tapping into top of vessel

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## 4.8 Circulators

### 4.8.1 Scope of Supply

Supplier shall provide 2 off installed circulator pumps

Supplier must also provide 1 off complete spare pump and 1 off maintenance kit for each pump.

Supplier shall provide control equipment (for example Variable Frequency Drive) to allow the pumps to be controlled by ISIS PLC Control System.

### 4.8.2 Design Requirements

The MCSS shall incorporate 2 circulators. In operation, one circulator will be active while the other is on cold standby.

Each circulator shall be sized for full system operation.

Standby circulator must be kept ready for operation – i.e. at operational temperature.

Circulator shall be certified for use in ATEX Zone 2 area as described in Section 5.7 of the General Requirements document (ISIS-TS1-UPG-SVS-Sp-0010).

NOTE that the circulator and drive must be certified together as a system.

Units shall incorporate the facility to be lifted individually.

Circulators shall be capable of providing stable flow at the design flow rate at the system operating conditions for all operational modes as described in Section 3.1 (except where noted).

In particular, the following design requirements should be noted:

#### Gas / Liquid / 2-Phase Flow Capability

The circulators shall be designed for Liquid operation but shall also operate as vapour blowers and be able to operate in conditions of 2-phase flow created during System Cool Down procedure.

Methane gas is introduced to the system and cooled to liquid while it is circulated. There is therefore an unavoidable period (typically 5 hours in the existing system) where the fluid is a mixture of liquid and gas phase, and the circulator must be able to operate in these conditions without damage to the circulator or loss of circulation of the fluid.

NOTE: it is acceptable for the flowrate achieved during cool down phase to differ from that at full system operation, i.e. the circulator can run at a reduced rate in order to cope with 2-phase flow.

However, the fluid flow must be maintained during the entire process at a flow rate sufficient to achieve constant and even cooling.

#### Pressure Fluctuation

During Methane Liquid Transfer and AFR procedures, pressure fluctuations are likely to occur within the system. In the current system, pressure fluctuation is typically  $\pm 1$  bar.

Circulators shall be capable of withstanding these conditions without damage.



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### 4.8.3 Maintenance

Routine maintenance should have a minimum period of 12 months.

Circulators shall be removable for maintenance without breaking vacuum in the coldbox vessel.

### 4.8.4 Control

The circulators shall be controlled from PLC located outside of the TSA. Supplier shall provide suitable pump control equipment, for example VFD, to interface with PLC. Speed control method to be agreed by STFC; this can be achieved using standard industrial network protocol, voltage or current loop.

Any VFD or electronics used for pump control must have the capability to be cabled, using an Atex compliant method, through the shield wall to the outside of the TSA - minimum 60m cable (suitable for routing along drag chains) required.

## 4.9 Separator

### 4.9.1 Function

Supplier is requested to provide a suitable phase separator to remove gaseous hydrogen from the liquid methane process stream

STFC recognises that it will not be possible for Supplier to test such a device at operational conditions. Suppliers shall provide calculation evidence to demonstrate suitability of the equipment, based on the following properties:

Fluid		Methane	Hydrogen
<b>Pressure</b>	<i>barA</i>	3.5	
<b>Temperature</b>	<i>K</i>	110	
<b>Density</b>	<i>kg/m<sup>3</sup></i>	425	0.77
<b>Dynamic Viscosity</b>	<i>μPa.S</i>	121.75	4.5
<b>Minimum Bubble Radius</b>	<i>mm</i>	NA	0.1 (or smaller)

Properties taken from NIST Thermophysical Properties of Fluid Systems - <http://webbook.nist.gov/chemistry/fluid/>

### 4.9.2 Additional Requirements:

Separator shall be accessible to allow future development work. Enclosing this equipment within a separate vacuum vessel would be an acceptable means of achieving this – see drawing: *Ref SI-5600-100 Sheet 3 – Detail A*

Separator connections to the main flow circuit shall be of cryogenic bayonet type or other suitable breakable connection, to allow vessel to be detached for future development work.

Separator function shall not adversely affect system performance or stability.

## 4.10 Filter

A 60μm filter is required in order to protect the circulator pumps from any debris accumulated in the system during manufacture.

Filter should be located immediately upstream of the circulator pumps.

The filter must have the facility to be removed for filter element replacement.

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Supplier to provide one spare filter element.

#### 4.11 Cryogenic Valves

Supplier should provide suitable valve arrangement to allow the system to be operated as described in Section 3.

Supplier to provide one complete spare and one maintenance kit for each valve type used.

All valves, except where specifically identified, shall be remotely operated by PLC control system.

Valves shall be fitted with suitable means to communicate position to PLC (Position switches).

Valves must have the provision to allow routine maintenance without breaking into coldbox vacuum.

Where/if 3-way diverter valves are used, they must be designed such that it is not possible to close off both outlets simultaneously.

Valves and ancillary equipment including actuators and position switches shall be certified for use in ATEX Zone 2 area as described in Section 5.7 of the General Requirements document (ISIS-TS1-UPG-SVS-Sp-0010).

Valves shall fail to safety (TBD on valve-by-valve basis during the Design Phase).

Valves should have the capability to be locked in position to allow maintenance.

Note that valve used to inject liquid into circuit during AFR operation must be capable of rapid operation as described in Section 3.1.5.

#### 4.12 Relief Devices

##### 4.12.1 Process Safety Relief Devices Valves

Supplier to provide appropriate safety relief devices to protect the system

Pressure Relief Valve Set Point: 55 PSIG (3.8 BarG)

Bursting Disc Set Point: 5 BarG

Safety Case shall be the total loss of vacuum in the entire moderator system

Relief devices will vent to ISIS Relief System pipework. STFC shall provide details of the Relief System pipework during Design Phase

##### 4.12.2 Vacuum Relief Devices

Supplier shall provide appropriate overpressure relief devices for the protection of vacuum equipment

Pressure Rating: 0.5 barG

Safety Case shall be a full bore pipe leak into the vacuum space.

Vacuum relief devices will vent to ISIS Relief System Pipework. STFC shall provide details of the vent System pipework during Design Phase.

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## 4.13 Instrumentation:

Supplier to provide suitable instrumentation to allow the system to be operated as described in Section 3.

All instrumentation shall be ATEX compliant, and supplier shall provide evidence of how this is to be achieved as part of the tender package.

Supplier to provide suggested Instrument List at Tender Stage.

Supplier to provide Finalised Instrument List for STFC agreement at completion of design stage.

### 4.13.1 Temperature Sensors (Control)

Temperature Sensors at locations TS71M used for control of heater HTR77M

Suppliers to install 2 x Temperature Sensors at this location for redundancy.

Sensing elements should be installed such that they are in direct contact with the methane fluid.

Sensor Type : Platinum Resistance Thermometer  
Required accuracy :  $\pm 0.1$  K at Operational Temperature  
Reproducibility :  $\pm 20$  mK at Operational Temperature

Supplier to terminate with connection suitable for ATEX requirements as described in Section 5.7 of the General Requirements document (ISIS-TS1-UPG-SVS-Sp-0010).

Wherever possible, it should be possible to extract and reinstall temperature sensors from the system without the need to break the coldbox vessel insulating vacuum, to allow for the replacement of failed sensors.

### 4.13.2 Temperature Sensors (Diagnostic)

Temperature Sensors at other locations are for use in system diagnostics only

Suppliers to install 1 x Temperature Sensor at each location.

Sensing elements should be installed such that they are in direct contact with the methane fluid.

Sensor Type : Platinum Resistance Thermometer  
Required accuracy :  $\pm 0.25$  K at Operational Temperature  
Reproducibility :  $\pm 20$  mK at Operational Temperature

Supplier to terminate with connection suitable for ATEX requirements as described in Section 5.7 of the General Requirements document (ISIS-TS1-UPG-SVS-Sp-0010).

Wherever possible, it should be possible to extract and reinstall temperature sensors from the system without the need to break the coldbox vessel insulating vacuum, to allow for the replacement of failed sensors.

### 4.13.3 Pressure Sensors

Supplier to provide pressure tapplings for sensor attachment at Coldbox Vessel Top Plate.

Pressure sensors shall be supplied by STFC.



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Supplier to terminate each pressure tapping with suitable tube fitting, to be determined during Design Phase.

#### 4.13.4 Liquid Level Sensors

Required for measuring liquid level in the Condenser Vessel and Dump Tank Vessel

Sensor should be Platinum Resistance Thermometer type, utilising thermal conductivity difference between liquid and gas phase.

Must be suitable for Atex Zone 2 use

Sensor should provide 10 positions to indicate different fluid levels. If fewer positions are to be used then this must be agreed with STFC. Sensor must provide a minimum of 4 positions. Appropriate levels to be determined during design phase.

Supplier to terminate with connection suitable for ATEX requirements as described in Section 5.7 of the General Requirements document (ISIS-TS1-UPG-SVS-Sp-0010).

It shall be possible to extract and reinstall Liquid Level Sensors from the system without the need to break the coldbox vessel insulating vacuum, to allow for the replacement of failed sensors.

#### 4.13.5 Flow Meter

Flow meter required for system diagnostics only – not used as part of system control.

Flow meter shall give a measurement of liquid methane flow rate during Normal System Operation.

Flow Meter type	:	Differential Pressure/Orifice Plate
Fluid Conditions	:	See Section 2
Flow Range	:	0 – 0.5 L/s*
Accuracy	:	± 5%
Output	:	0-10 V

Electronics cannot be located within the TSA. Equipment must have the capability to be cabled through the shield wall to the outside of the TSA - minimum 60m cable (suitable for routing along drag chains) required.

Flow meter pressure sensors shall be able to withstand pressure fluctuation encountered during Liquid Transfer and AFR operations, as described in Section 3.1.

\*To be confirmed during design phase, dependent on maximum flow capacity of system.

### 4.14 Heater

#### 4.14.1 Function

The system shall use a heater (shown as HTR77M on suggested P&ID Ref: *SI-5700-100*) in order to provide temperature control to the methane. The heater shall be used to ‘top up’ the total system heat load to a constant value before the methane enters the Cryogenerator Head Heat Exchanger.

Existing system uses a cartridge heater submerged directly into the liquid methane.

Required Power: 0 – 1500 W

Heater reaction time shall be sufficient to meet temperature stability requirement.

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Heater shall be compliant with ATEX requirements as described in Section 5.7 of the General Requirements document (ISIS-TS1-UPG-SVS-Sp-0010).

Heater shall incorporate a temperature sensor to allow PLC to monitor performance.

Heater shall include the functionality to limit power/temperature to a specified value (PLC control is acceptable)

Heater shall be accessible for maintenance/replacement.

## 5 Interfaces

### 5.1 Transfer Line and Moderator

The MCSS is connected to the moderator vessel via a vacuum insulated transfer line by means of concentric flow and return lines.

The transfer line is routed through existing concrete shielding blocks and its location, as shown on Layout Drawing: *Ref SI-5600-100 Sheet 2*, is therefore fixed.

An adaptor piece, provided by STFC, will be used to connect between the coldbox top plate and the point at which the transfer line enters the shielding.

A suitable connection shall be provided for this adaptor piece – to be determined during Design Phase.

Moderator Vessel Volume :	:	0.5 Litres Approx.
Transfer Line Total Volume :	:	14.5 Litres Approx.
Pressure Drop across Moderator and Transfer Lines at Steady State Operating Conditions	:	0.6 Bar

### 5.2 Cryogenerator

The Cryogenerator location, as shown on Layout Drawing *Ref SI-5600-100 Sheet 4* should be considered fixed for quotation purpose.

Cryogenerator Cone Connection is shown in Drawing Ref: *SI-7047-320* (part of Drawing Pack *SI-7047-400*)

### 5.3 Methane Supply / Vent

Methane Supply pressure is 4 BarA

Pressure in the vent system is controlled between 1.2 BarA and 1.5 BarA

Methane supply and vent pipework will be installed by STFC

Supplier to terminate with pipe stub or other suitable connection type (to be agreed during Design Phase), so allow connection into STFC pipework systems.

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## 5.4 Relief System

Equipment shall be connected into ISIS Relief System by STFC. The relief system incorporates Pressure Surge Vessels in order to absorb system pressure fluctuations and prevent frequent relief device operation.

Total number of connections shall be minimised. Wherever possible, connections to the relief system shall be combined with supply/vent connections.

## 5.5 Vacuum System

Supplier shall provide vacuum connections, located on under-side of the coldbox vacuum vessel to allow STFC to connect into existing vacuum system.

Supplier shall provide suitable vacuum connections where additional separate vacuum vessels are used, for example to enclose Dump Tank valve.

Connection size to be agreed with STFC during Design Phase

Preferred connection type shall be CF flange. ISO-K or ISO KF Flange shall also be acceptable.